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Network analysis reveals the associations of past quit experiences on current smoking behavior and motivation to quit

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Network analysis reveals the associations of past quit experiences on current smoking behavior and motivation to quit

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Abstract

Network analysis reveals the associations of past quit experiences on current smoking behavior and motivation to quit

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Smoking is a leading cause of morbidity and mortality in the United States. While most smokers endorse a desire to quit, achieving abstinence is notoriously difficult. Network analysis is a method for understanding the complex relationships of factors that maintain smoking behavior and motivation to quit. This study examined self-report prescreen data from treatment-seeking smokers (*N*=3,913). The number of prior quit attempts and withdrawal symptoms experienced, as well as current smoking behavior and motivation to quit were modeled as interconnected nodes in a network. Two key network metrics were examined: 1) edge weights, which quantify the strength and direction of the associations of interest, and 2) the sum of each node's edge weights, which quantifies the expected influence of a node on the overall network. The withdrawal symptom of craving, r = 0.10, 95% CI [0.07, 0.13] and digestive problems, r = -0.06, 95% CI [-0.09, -0.03], had the strongest positive and negative association with daily cigarettes, respectively. The number of prior quit attempts, r = 0.17, 95% CI [0.14, 0.20],

concentration problems, r = -0.04, 95% CI [-0.027, -0.01], showed the strongest positive and negative associations, respectively, with current motivation to quit. Nodes with significant links to current smoking and motivation to quit were also among the most influential in the overall network. Findings suggest prior quit experiences and consequences associated with withdrawal symptoms may differentially relate to maintenance of smoking behavior and motivation to quit in treatment-seeking smokers. Interventions targeting key withdrawal symptoms may enhance motivation to quit.

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Chapter 1: Introduction[1]

Tobacco use is a global public health burden. In the United States, where the current study took place, smoking cigarettes serves as a major contributor to morbidity and mortality rates in the United States (U.S. Department of Health and Human Services, 2014). Approximately 480,000 adults die each year as a result of smoking cigarettes or exposure to secondhand smoke (U.S. Department of Health and Human Services, 2014). Although the prevalence of cigarette smoking in recent years has been in overall decline, approximately 19% (47.8 million) of U.S. adults use tobacco products and 14% (34.3 million) continue to smoke cigarettes (Wang et al., 2018). It is estimated that 70% of U.S. smokers indicate a desire to quit and over 50% make a quit attempt annually (CDC, 2011), however only a small proportion (6%) manage to achieve abstinence long term (CDC, 2011). As most cessation attempts rarely result in abstinence, it is necessary to examine novel approaches to understanding maintenance behavior and barriers to smoking cessation.

The process of achieving and maintaining abstinence has been divided into four phases: motivation (period leading up to readiness to make a quit attempt), pre-cessation (weeks prior to quit attempt after decision to quit is made), cessation (two weeks immediately following quit attempt), and maintenance (weeks post-quit which focus on maintaining abstinence; Baker et al., 2011). While each phase offers unique challenges and opportunities for clinical intervention, increasing motivation is key for stimulating quit attempts (Baker et al., 2011). Indeed, motivation to quit is an important initial factor in the smoking cessation process, as it prompts action to stop

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smoking and is predictive of the likelihood of making quit attempts (Baker et al., 2011; Borland et al., 2010).

Understanding factors that are associated with the maintenance of current smoking behavior and motivation to quit have important implications for enhancing cessation interventions. Evidence suggests past quit attempts are predictive of future attempts (Vangeli et al., 2011), as it takes an estimate of 8-10 attempts (CDC , 2002), although for many smokers attempts can extend beyond 30 tries before quitting for good (Chaiton et al., 2016). However, the occurrence of aversive withdrawal symptoms experienced during previous quit attempts may be associated with motivation to make a future quit attempt. Specifically, physiological (e.g., intense cravings, difficulty concentrating, weight gain) and psychological consequences (e.g., increased negative affect, lower positive affect) have been associated with maintenance of current smoking behaviors and relapse (Aguirre et al., 2015).

Network analysis has become a powerful approach to elucidate the fine-grained relationships among the elements (e.g., symptoms) that make up psychological constructs (e.g., disorders; Epskamp & Fried, 2018). The key components of networks are nodes, which represent the variables in the network, and edges, which can represent the strength and sign of associations (i.e., positive or negative) between nodes. Partial correlations are typically used to calculate edges; although the partial correlation coefficients are related to what is calculated in a multiple regression analysis, networks are useful for generating hypotheses that may not be apparent in a multiple regression analysis. For example, whereas multiple regression analysis yields the strength of the relationship between dependent and independent variables, partial correlation networks additionally map the relationships among all variables. This additional feature can help generate a variety of hypotheses about (1) indirect associations (e.g., when networks reveal

indirect paths from independent variables to the variable of interest); (2) redundant or latent variables (e.g., when networks show that two or more nodes cluster together); and (3) key nodes (e.g., when centrality metrics show that some nodes have stronger and more broadly distributed associations across the network). The network approach has been applied to understand a wide range of mental health concerns, such as depression and anxiety (Beard et al., 2016), Posttraumatic Stress Disorder (McNally et al., 2015), and substance abuse and dependence (Lydon-Staley et al., 2018; Rhemtulla et al., 2016). When applied to tobacco withdrawal, a network approach identified symptoms relevant to the experience of withdrawal (e.g., restlessness, affective symptoms, sleep problems; Rhemtulla et al., 2016). Furthermore, the tobacco withdrawal network structure proved relatively stable across four treatment timepoints (Rhemtulla et al., 2016), which suggests targeting relevant withdrawal symptoms may induce optimal treatment for smoking cessation interventions. The current study expands on prior network analyses examining nicotine withdrawal to identify relevant clusters of withdrawal symptoms and their associations with current smoking habits and motivation to quit. Specifically, we applied network analysis to examine how the number of past quit attempts, withdrawal symptoms and other consequences of prior quit attempts impacted current smoking behavior (e.g., daily cigarette use) and motivation to quit in a large treatment-seeking sample.

Chapter 2: Methods[2]

PARTICIPANTS AND PROCEDURES

Participants were 3,913 (2337 [59.72%] female; M_{age} = 37.26, SD = 11.14) treatment-seeking adult smokers who completed online eligibility screening procedures for smoking cessation interventions (i.e., Approach bias retraining [ABR] to augment Cognitive Behavioral Therapy for smoking cessation and Nicotine Replacement Therapy [NRT], Smits, et al., 2019; exercise and telephone intervention combined with NRT, Smits, Zvolensky, et al., 2019). Participants were recruited via community-based and online strategies (e.g., social media, Craigslist, flyers, newspaper advertisements) in the central Texas area. Advertisement for the ABR smoking intervention stated eligible individuals could receive 7 weeks of free individual smoking cessation treatment, NRT, and completion of a computer joystick task thought to augment smoking cessation treatment. Advertisement for the exercise intervention stated eligible individuals could receive 15 weeks of a free YMCA gym membership, smoking cessation counseling with the Texas Tobacco Quitline, and NRT. While the clinical trials applied a variety of inclusion and exclusion criteria, the current study included all participants with complete screening data on the variables of interest. All participants underwent a University of Texas at Austin Institutional Review Board-approved informed consent process prior to completing the eligibility screening.

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MEASURES

Participants completed self-report measures of demographic information (e.g., age, sex). To capture smoking history and patterns we used the Smoking History Questionnaire (SHQ; Brown et al., 2002). The SHQ is a 30-item self-report measure that includes items pertaining to daily cigarette smoking rate, age of onset of initiation, years of being a regular smoker, number of prior quit attempts, and previous withdrawal symptoms. For the current analysis we modeled self-reported seriousness of problems experienced during previous quit attempts on a 5-point Likert ranging from "not at all" to "extremely": weight gain, increased eating, digestive problems, nausea, headaches, drowsiness, depression or low mood, fatigue, insomnia, difficulty concentrating, heart pounding or sweating, decreased heart rate, irritability, restlessness, anxiety, and craving for tobacco. Respondents also reported their motivation to quit smoking on an 10-point Likert-type scale, with 1 being "not at all motivated" and 10 being "extremely motivated"(Smits, et al., 2019; Smits et al., 2020).

DATA ANALYSIS

Connections between the number of prior quit attempts, withdrawal symptoms experienced, current smoking behavior, and current motivation to quit were modeled in a network in which edges represent partial associations between nodes (i.e., variables), after controlling for all other nodes in the network. Data were preprocessed to identify nodes with near zero variance, and to identify redundant nodes (Golino & Christensen, 2020). Redundant nodes can occur when two or more items in a self-report measure sufficiently overlap (e.g., drowsiness and fatigue); rather than making *a priori* assumptions about which nodes were redundant, these were identified using the weighted topological overlap approach (Golino & Christensen, 2020), and combined with latent variable scoring. Networks were estimated in a bootstrapping

procedure (1,000 replications) using Spearman correlations, which can yield more stable estimates when data are skewed, without regularization, which can bias edge estimates (Epskamp & Fried, 2018; Fried et al., 2020; Williams et al., 2019). Two key metrics were examined from the bootstrapped networks with 95% confidence intervals (CI): 1) edge weights linking prior quit experiences to current smoking behavior and motivation to quit, and 2) the metric of "expected influence" (Robinaugh et al., 2016), which is calculated by summing each node's edge weights, which are the associations to nodes across the entire network. Expected influence was proposed as an alternative to other centrality metrics that do not distinguish between positive and negative edges, such as strength centrality, which takes the sum of the absolute values of the edges (Robinaugh et al., 2016). All analyses were conducted in R (Team, 2013), and complete outputs with package versions are provided in supplementary material.

Chapter 3: Results[3]

Participants reported an average of 3.87 prior quit attempts (SD = 2.24), a current daily cigarette average of 13.22 (SD = 7.56), and a high motivation to quit (M = 7.69, SD = 1.68). No nodes were excluded due to near zero variance. Figure 1 shows the estimated network which included 14 nodes after several highly overlapping withdrawal symptoms were combined in preprocessing: increased weight and appetite; drowsiness and fatigue; heart pounding, sweating, and reduced heart rate; anxiety, irritability, and restlessness. There were 56 (61.54%) significant edges in the network out of 91 potential edges, of which five showed connections to current smoking and five showed connections to motivation to quit, after controlling for all other nodes in the network including number of prior quit attempts (Figure 2a). Specifically, the withdrawal symptoms of craving, r = 0.10, 95% CI [0.07, 0.13], and anxiety+irritability+restlessness, r = 0.04, 95% CI [0.01, 0.07], were positively associated with current smoking, whereas digestive problems, r = -0.06, 95% CI [-0.09, -0.03], drowsiness+fatigue, r = -0.04, 95% CI [-0.07, -0.01], and increased weight+appetite, r = -0.04, 95% CI [-0.07, -0.004], were each negatively associated with current smoking. The number of prior quit attempts showed the strongest positive association with current motivation to quit, r = 0.17, 95% CI [0.14, 0.20]. The withdrawal symptoms of increased weight+appetite, r = 0.06, 95% CI [0.03, 0.09], and craving, r = 0.04, 95% CI [0.004, 0.07], also showed positive links to quit motivation, whereas concentration problems, r = -0.04, 95% CI [-0.027, -0.01], and depression, r = -0.03, 95% CI [-0.06, -0.002], each showed negative links to quit motivation. Figure 2b summarizes the expected influence of each of the 14 nodes in the network. The anxiety+irritability+restlessness node was

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significantly more influential than all other nodes in the network, through its positive links with other withdrawal symptoms. Moreover, several additional nodes with significant links to current smoking and motivation to quit were also among the most influential in the overall network, including drowsiness+fatigue, concentration problems, and depression.

Chapter 4: Discussion[4]

The current study applied a network approach to evaluate how withdrawal sensations and other consequences from past quit attempts impact current smoking behavior and motivation to quit in treatment-seeking smokers. The withdrawal symptom of nicotine craving had the strongest association to current smoking behaviors, such that higher craving was linked to greater daily cigarette count. The experience of anxiety+irritability+restlessness in past quit attempts also showed a small positive association with daily cigarette use. Elevated cravings and negative affect (e.g., anxiety, irritability, restlessness) during previous quit attempts may reflect daily patterns of nicotine withdrawal and serve to maintain current smoking behavior as a withdrawal regulation strategy. This interpretation is consistent with extant work showing that higher craving and restlessness are predictive of increased subsequent smoking, and increased smoking is predictive of lower negative affect (Chandra et al., 2011). The observation that factors associated with digestion, appetite, and fatigue displayed small, yet significant negative associations with current smoking behavior is perhaps surprising as there is some research indicating that smoking may be used as a method to control weight (Cawley et al., 2016; White et al., 2007).

Past quit attempts had the strongest positive associations with the motivation to quit, even after controlling for all other consequences related to quitting. This is supported by previous work suggesting previous quit attempts are predictors of future attempts (Baker et al., 2011; Vangeli et al., 2011). Contrary to previous research findings (Baker et al., 2011; Clark et al., 2004), problems with weight gain and higher cravings were associated with increased motivation

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to quit smoking. It is possible be that individuals who experienced aversive consequences in previous quit attempts (e.g., weight gain, craving) are more motivated to quit with the aid of a treatment program (Garey et al., 2016). Indeed, Garey et al. (2016) theorized smokers who smoke to reduce negative affect may recognize the need for quitting assistance and thus are more likely to initiate treatment. Problems with concentration and the experience of depression in past quit attempts were identified as key factors that reduce subsequent motivation to quit. Because depressed mood and trouble concentrating are associated with numerous impairments (e.g., poor academic and work performance, social relationships) and reduced quality of life (Kessler, 2012), it is not surprising that these symptoms would negatively impact current motivation to quit.

Anxiety+irritability+restlessness shared positive links with other withdrawal symptoms and emerged as the most influential node in the network. Additionally, drowsiness+fatigue, concentration problems, and depression were also influential in the overall network. These results align with Lydon-Staley et al., (2018) findings that restlessness and affective symptoms (i.e., depressed mood and anxiety) had the highest strength centrality in a tobacco withdrawal network. This finding suggests restlessness and affective symptoms may be particularly influential in the maintenance of smoking behaviors and may be promising clinical targets to boost motivation to quit.

LIMITATIONS AND FUTURE DIRECTIONS

The cross-sectional nature of this study limits use of drawing causal inferences and leaves open the possibility of third-variable explanations. Unfortunately, we were unable to account for additional variables known to impact smoking behaviors and cessation motivation (e.g., psychiatric diagnosis, perceived addiction) during the pre-screen (Lasser et al., 2000; Mathew et

al., 2017; Perski et al., 2019). Moreover, it is important to acknowledge the distinction between cross-sectional and temporal networks from the broader network literature (Epskamp et al., 2018). Networks calculated on repeated observations allow exploration of directional relationships across time, and not surprisingly, temporal relations have diverged from cross-sectional ones (Bos et al., 2017). Nevertheless, there is evidence from the treatment literature that cross-sectional network analyses can demonstrate associations with longitudinal processes in the context of prolonged grief (Robinaugh et al., 2016), and treatment for PTSD (Papini et al., 2020), and social anxiety disorder (Rodebaugh et al., 2018). In the context of our network analysis, future work can test several competing hypotheses generated by our finding that participants who experienced more anxiety+irritability+restlessness in prior quit attempts showed less motivation to quit smoking: 1) addressing anxiety concerns around quitting may enhance motivation; 2) enhancing motivation may lead to a reduction in reported anxiety about prior quit attempts; or 3) these associations are not causal in nature and intervening on either of these variables may reduce or eliminate their association. Another limitation, which is difficult to avoid given the retroactive nature of assessing smoking history and previous quit attempts, is recall bias (Shiffman et al., 1997; Trull & Ebner-Priemer, 2014). Although the Smoking History Questionnaire is a valid and well used measure in smoking cessation literature, it is likely that the accurate number of previous quit attempts and information relevant to relapse (e.g., withdrawal sensations) may be vulnerable to retrospective biases. Lastly, our single-item assessment of motivation is not a validated scale and reflects only one aspect, namely desire to quit. Given this is a treatment-seeking sample, it would be beneficial to assess additional aspects of motivation related to smoking cessation and treatment using an empirically validated measure. Future work would benefit from including other questionnaires, such as the Motivational Aspects

of Smoking Cessation Questionnaire (MASC) which assesses motivation to seek smoking cessation information or take part in treatment (Rundmo et al., 1997).

CONCLUSION

This study yields findings that encourage consideration of individual withdrawal symptoms and related cessation consequences from previous quit attempts, as consequences related to quitting differentially influence current smoking habits motivation to quit in treatment-seeking smokers. Our results suggest that anxiety-related concerns in particular are key factors that influence smoking maintenance and motivation to make a future quit attempt. Smoking interventions that target key clusters of withdrawal symptoms may enhance motivation to quit smoking and reduce daily use of cigarettes among treatment-seeking smokers.

Figures

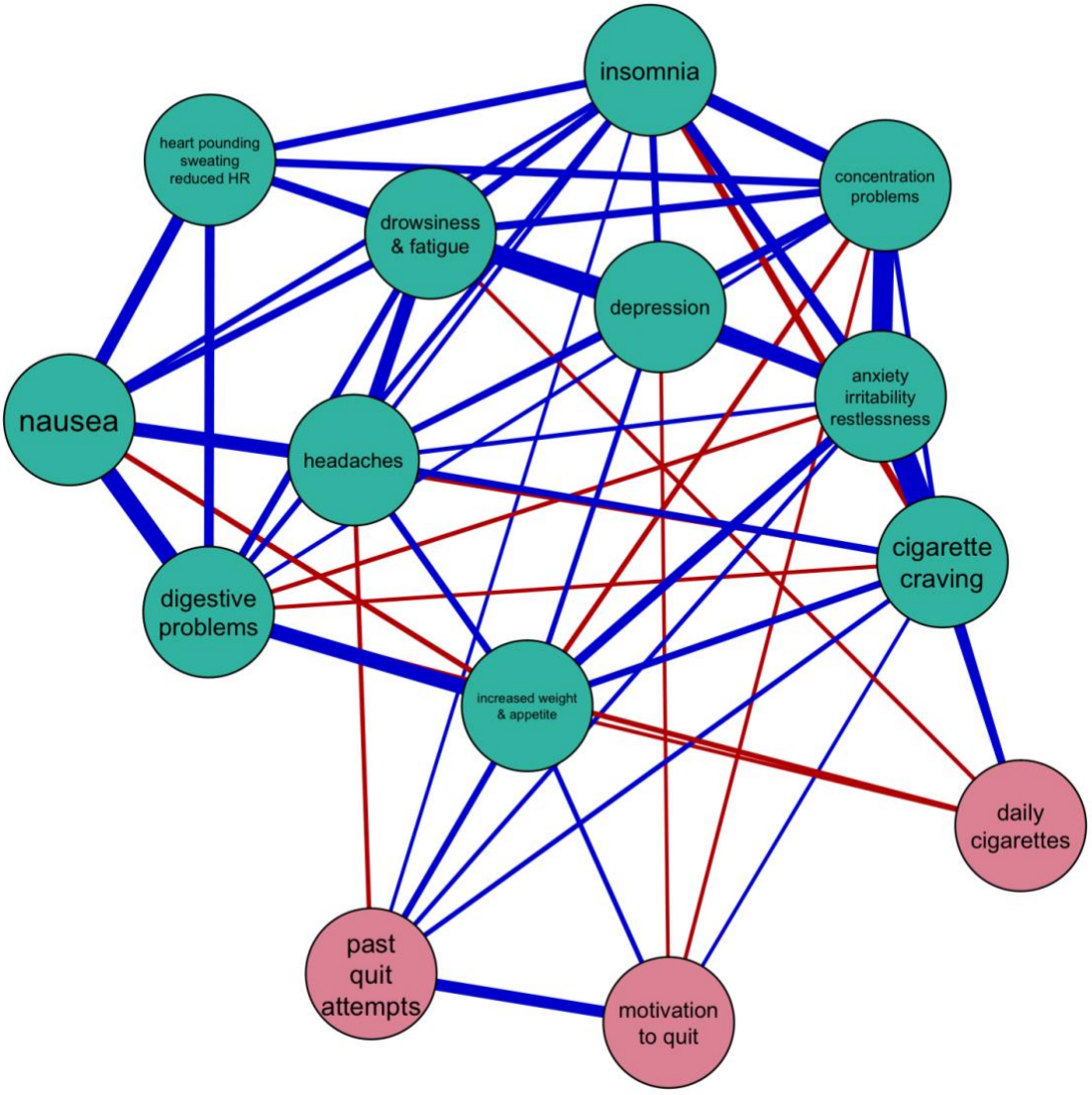

Figure 1. Network graph. Note the layout of the network is not interpretable in a straightforward fashion. Blue edges represent significant positive associations between nodes, and red edges represent significant negative associations. Edge thickness corresponds to the strength of the association. The bootstrapped network was thresholded such that edges with 95% CIs that crossed zero were pruned from the network.

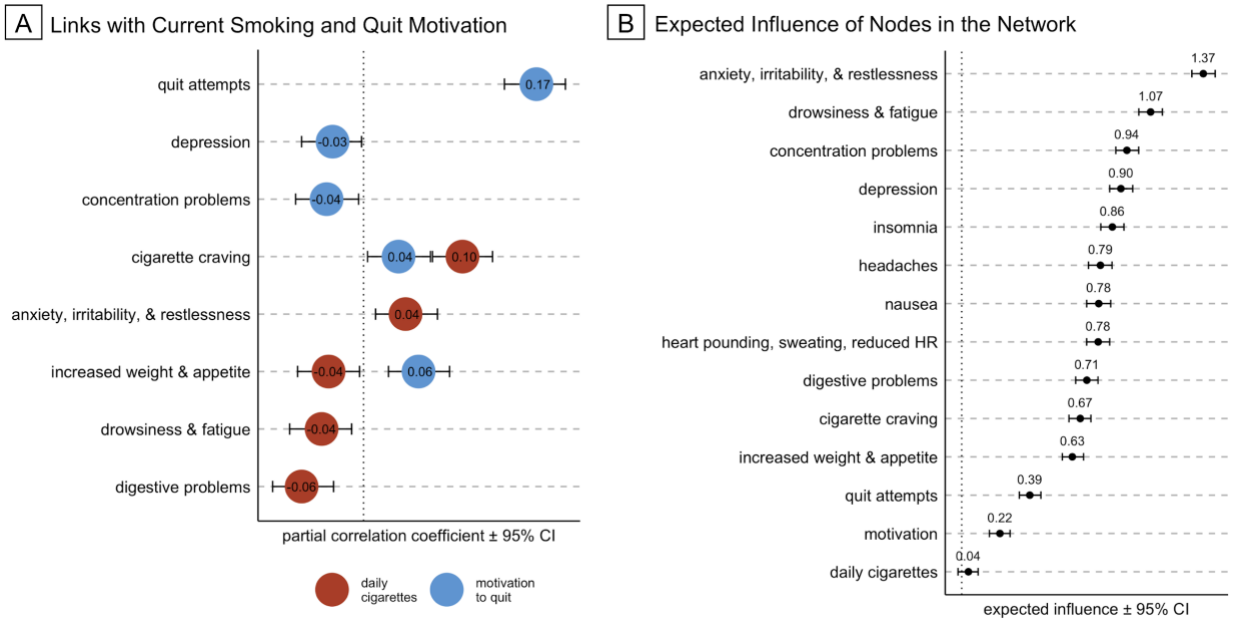

Figure 2. Significant links with current smoking and quit motivation (A) and expected influence of nodes in the network (B). Mean values are depicted with 95% CI. CIs that do not cross zero are significant at $p < .05$.

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